Successful Launch & Commission of TripleSat Constellation - Start of Commercial Operational Services

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Twenty First Century Aerospace Technology (21AT Asia)

JACIE Workshop 2016

The Company

二十一世纪空间技术应用股份有限公司
Twenty First Century Aerospace Tech

- EO satellite operator based in Beijing, 400+ employees
- Since 2005, the company has been providing EO data and value added service in China
- EO satellite resources:
  - ✓ Beijing-1, 4m PAN/32m MS, 2005~2012
  - ✓ 2.5m PAN/10m MS payload on Practice-9 Satellite
  - ✓ TripeSat Constellation, 1m PAN/4m MS, has been launched on 10 July 2015
- Beijing -1 International data distribution through DMC and disaster response through International Charter
- 21AT Asia in Singapore will provide TripleSat Constellation imagery to worldwide customers

Imagery Data Storage

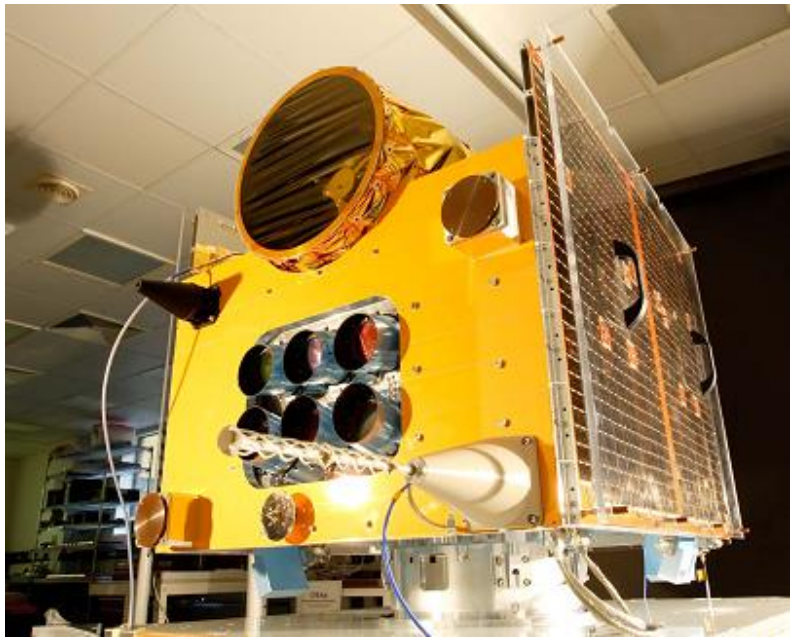
Ground station in Singapore

First Commercial EO Satellite Operator in China

21AT Satellite Resources: Beijing-1 Small Satellite

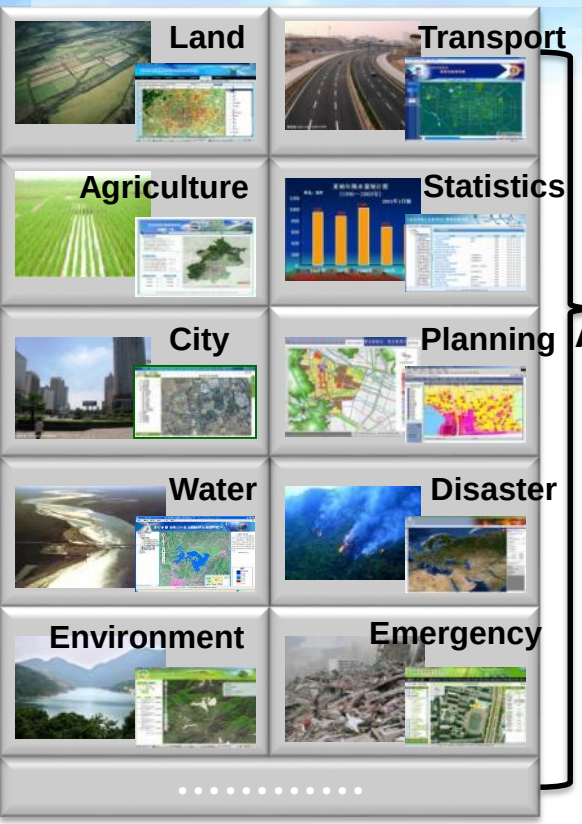
Orbit	**SSO 686km**
GSD	**4m PAN, 32m MS**
Swath Width	**24km/600km**
MS bands	**G/R/NIR**
Off-pointing	**±30°**
Revisit	**1 day for 32m MS; 5 day for 4m PAN**

Launched in 27 Oct. 2005
Operated for 7 yrs, exceed 5yrs design lifetime



DMC+4 /Beijing-1

Geospatial Data Base and its Applications



Decision Making
Social Focus

Gov Management
Application Service

Sharing
Interface

Data Sharing
Standard

Service
Sharing
Standard

Data Resources
Center

- Data
- Information
- Software

Data Resources
Share Services

Geospatial Data Base

Spatial Data

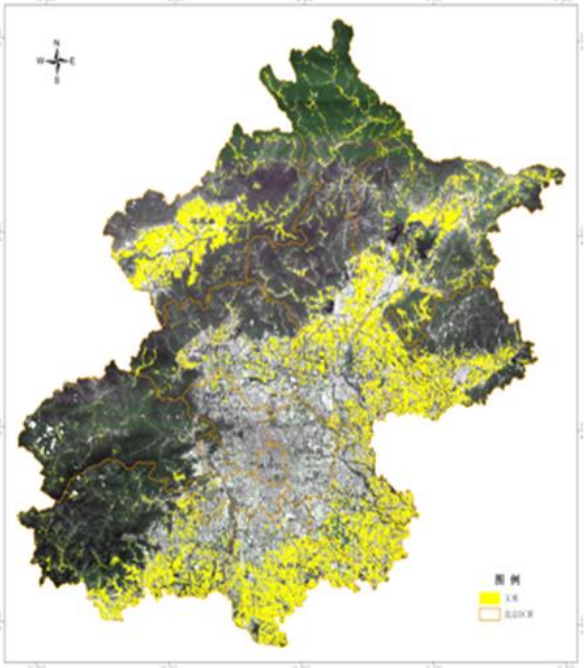
Dynamic Acquisition

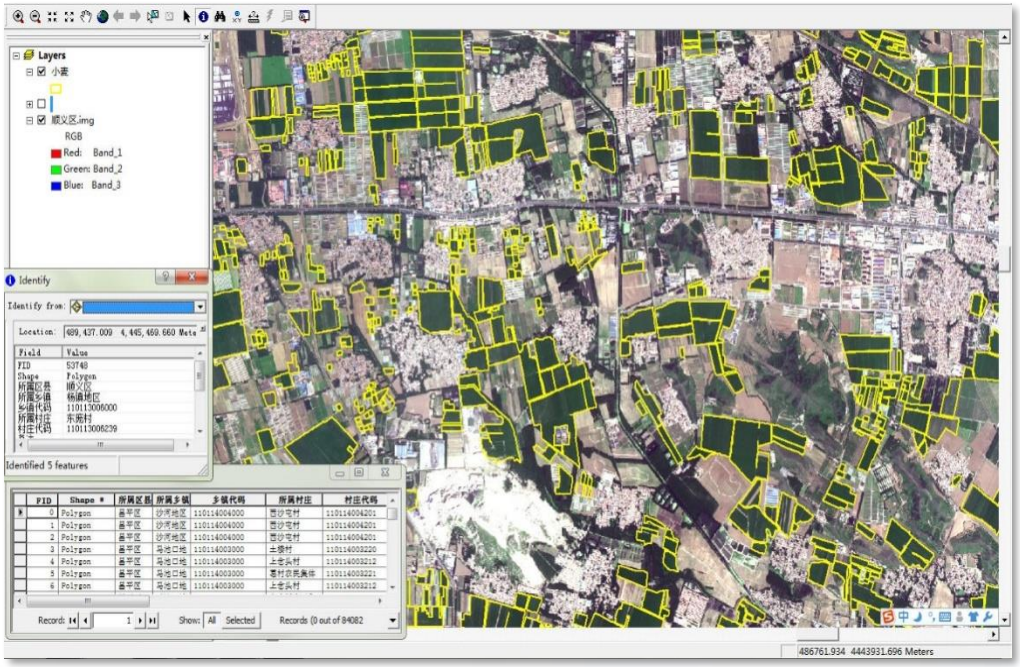
Government Data

Agriculture Statistic Survey

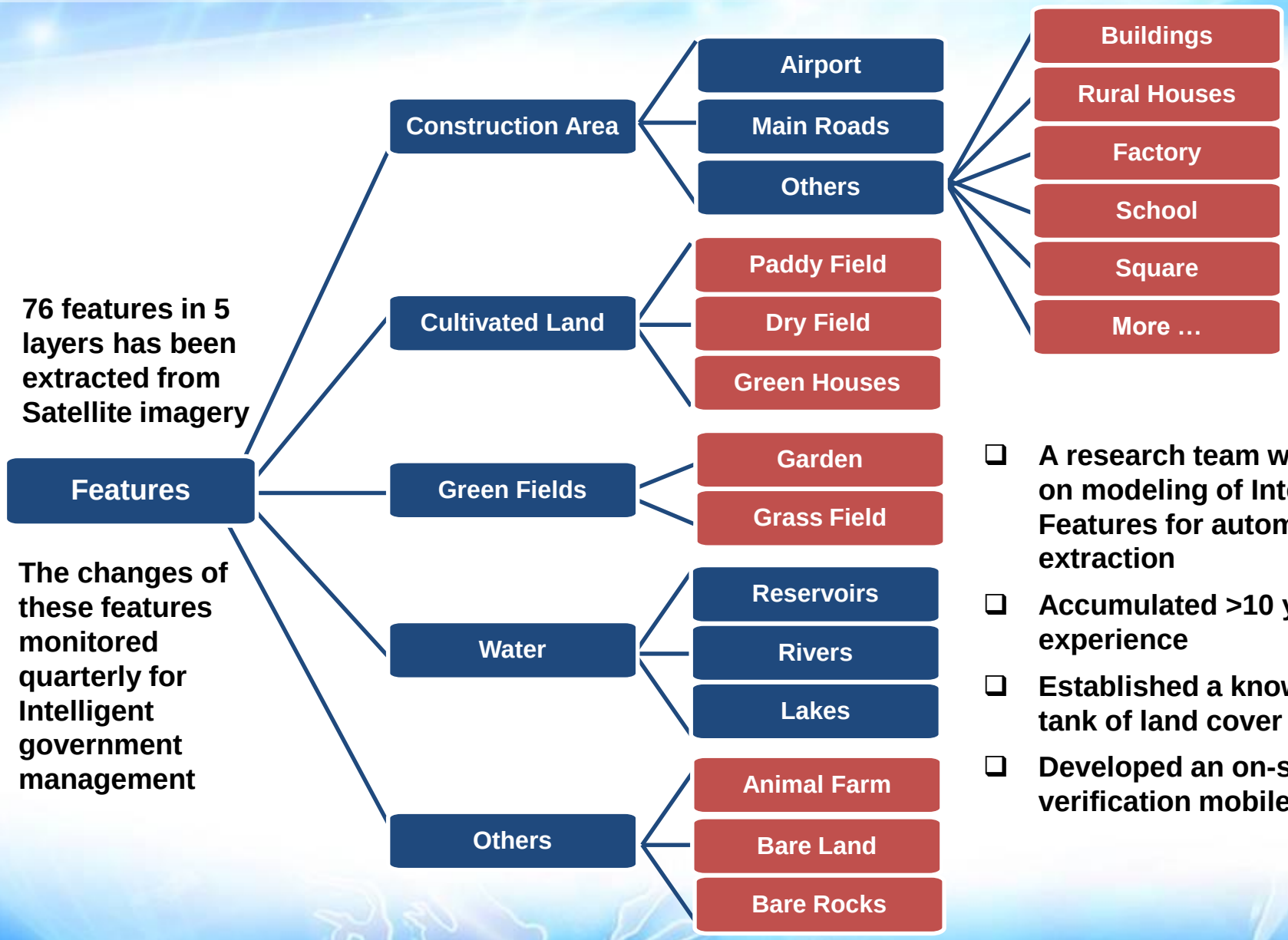
Beijing Major Crops Monitoring (Wheat and Corn)

- Implement regional wheat and corn monitoring 3 times per year
- Accurate extraction of field area
  - Assist compensation distribution based on area
- Statistic accuracy > 95%





Information Extraction from Satellite Imagery

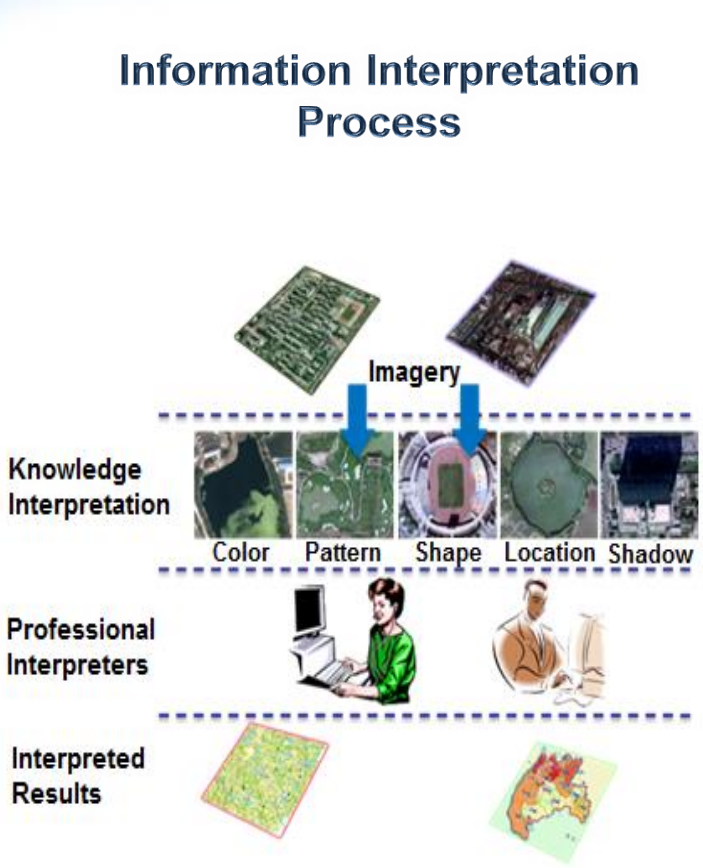


76 features in 5 layers has been extracted from Satellite imagery

The changes of these features monitored quarterly for Intelligent government management

- **A research team working on modeling of Interested Features for automatic extraction**
- **Accumulated >10 years experience**
- **Established a knowledge tank of land cover features**
- **Developed an on-site verification mobile terminal**

Information Extraction Products



Information Extraction Products

Open Golf Course

Building

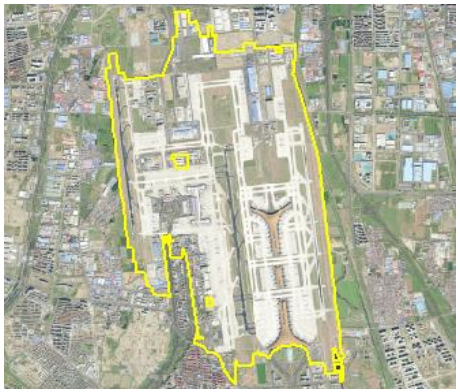
Information Extraction Products

Open Stadium

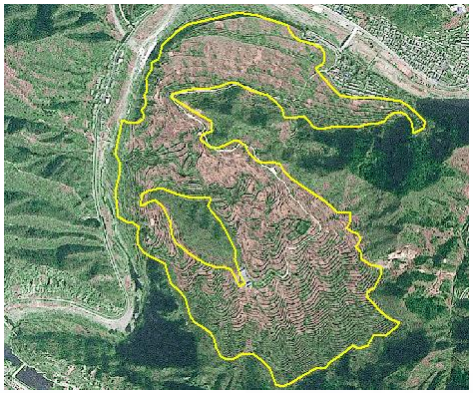
Cemetery

Information Extraction Products

Airport



Terraced Fields



Information Extraction Products

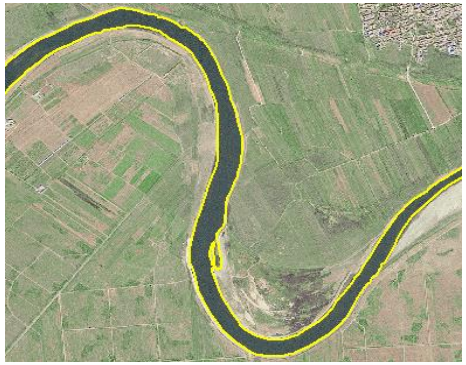
Dry land

Broad-leaved Forest

Information Extraction Products

Open Pit

River



Information Extraction Products

Power station

Highway

Change Detection of Interested Features

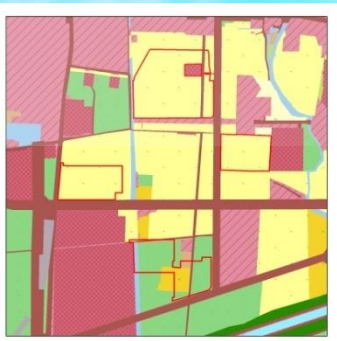
Regular remote sensing data acquisition and processing

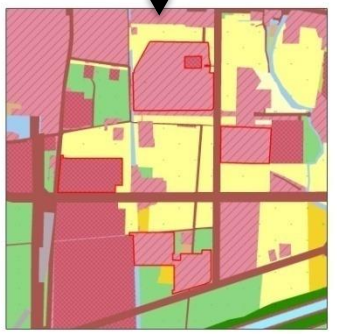
Change-information extraction

Legal

Compare with government administrative data

Illegal





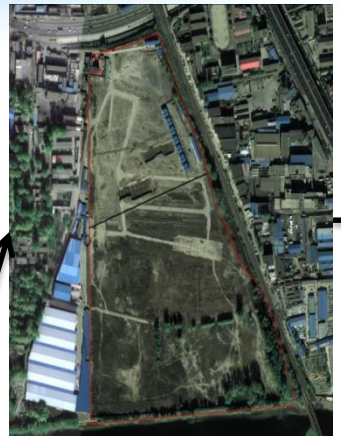
Update the change-information to the spatial database

On-site verification with mobile device

Dismantlement enforcement support

Change Monitoring of Targeted Areas

Project boundary digitization



Land leveling

Local construction

On-site verification and attribute collection with mobile device

Establish and update the spatial database

Global construction

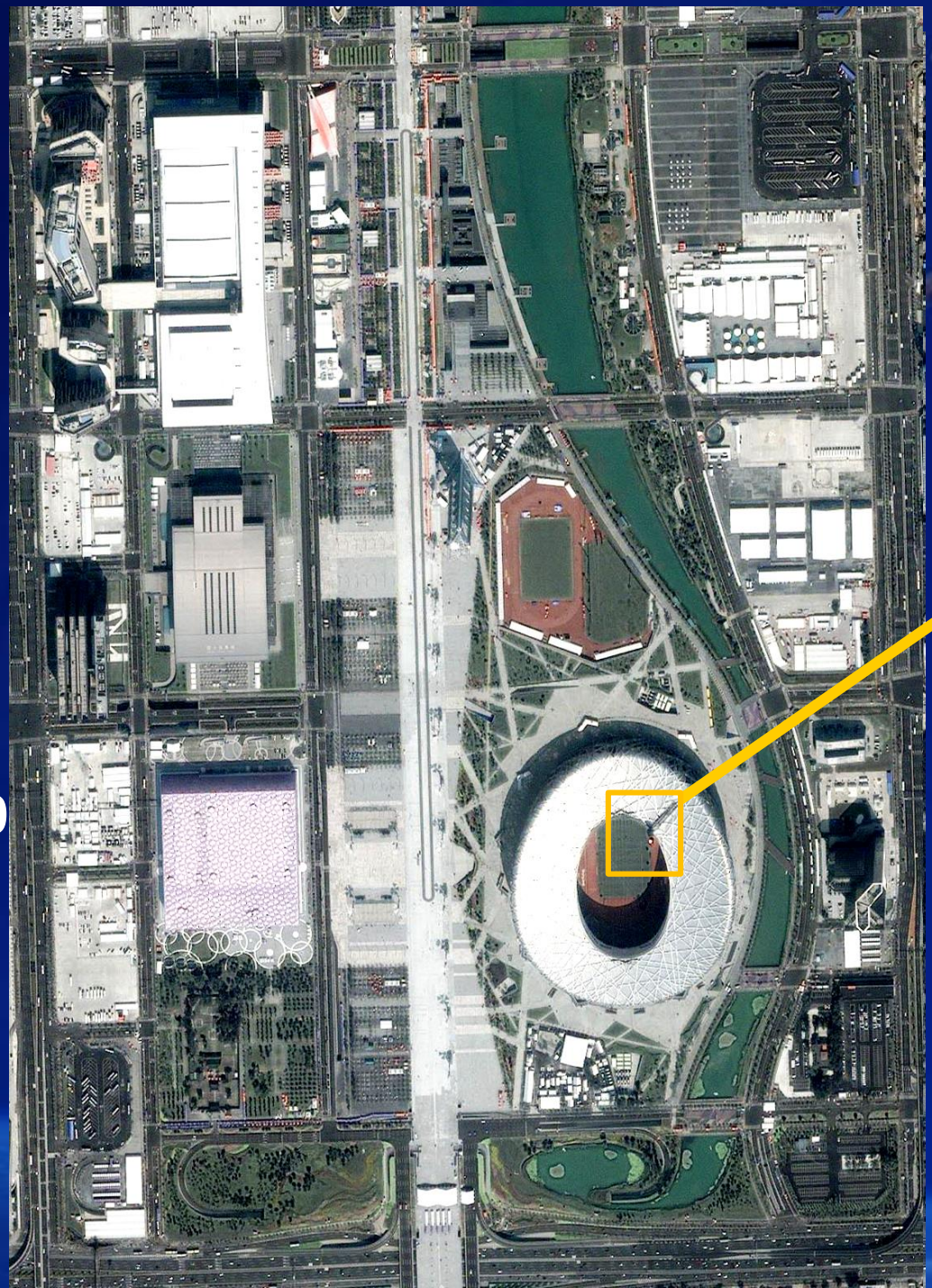
Completion

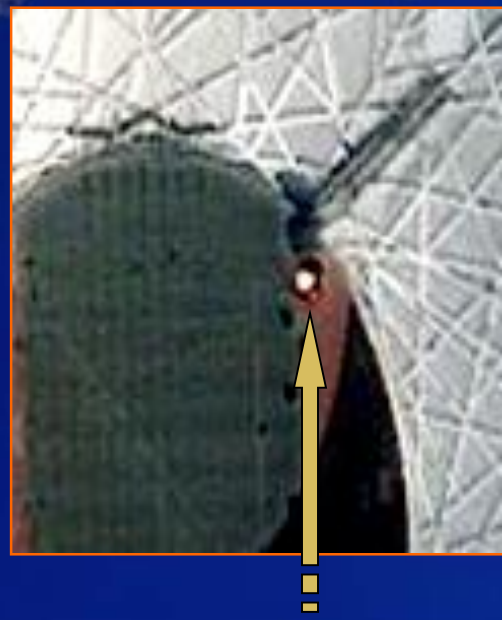
2004-8

2006-8

2007-10

2008-8



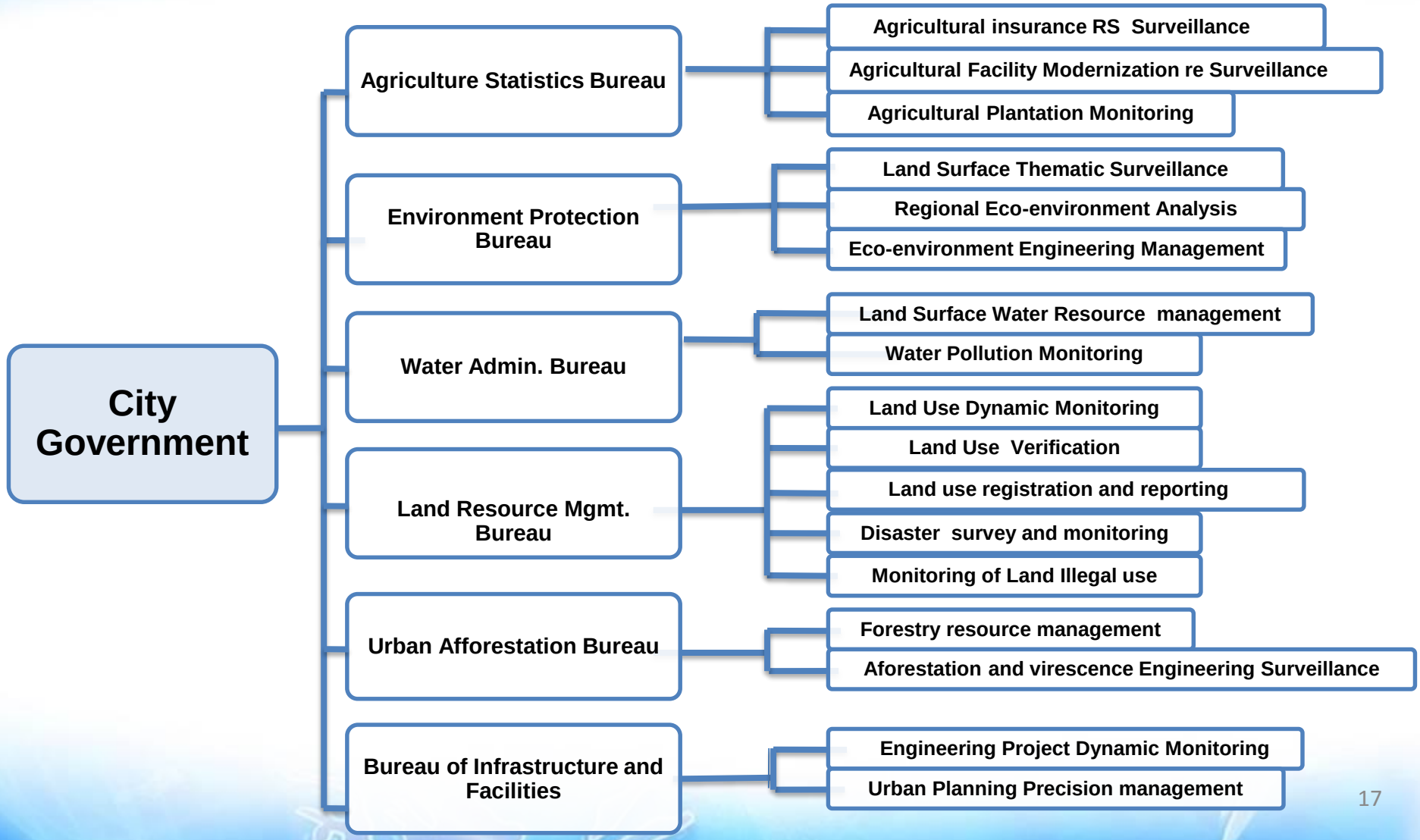


Olympic flame

Urban Change Monitoring— to Support the Application Beijing Olympic Game 2008

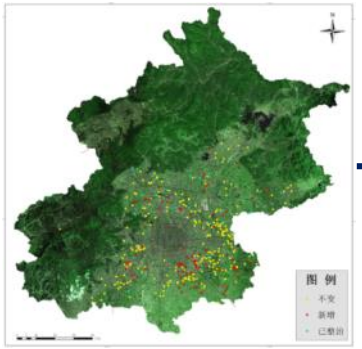
Services Overview of Intelligent City Management System

More than 100 Services for 10 government departments that can be classified into 6 categories. The following is the six major government departments served:

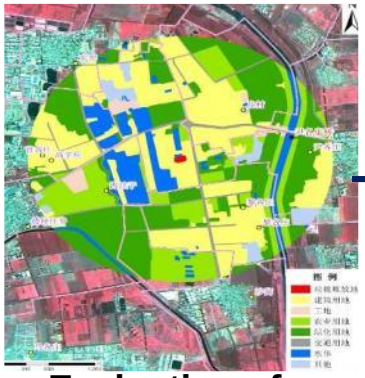


Illegal Dumping Rubbish Surveillance

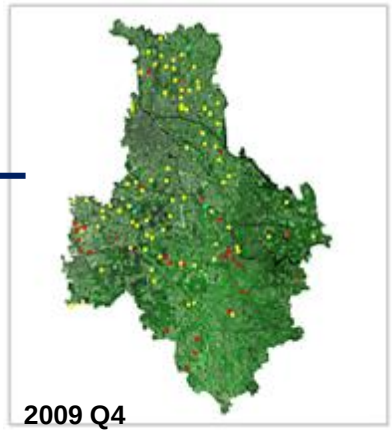
Using remote sensing technology to solve “Rubbish Surround City” problem



Quarterly monitoring location of rubbish sites



Evaluation of clearing priority



Report to local government department

Comparison of management effect

Illegal Dumping Rubbish Surveillance

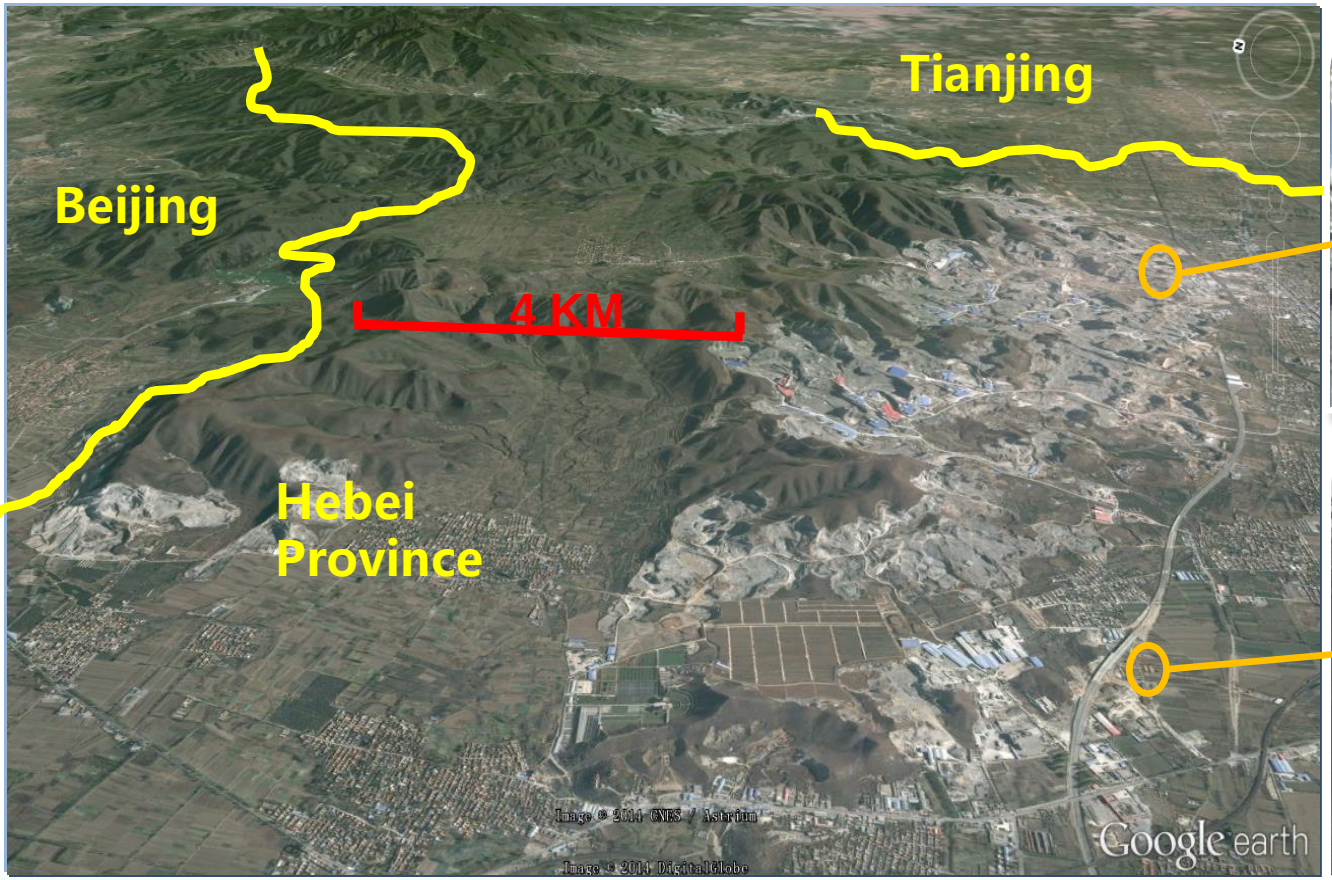
Before

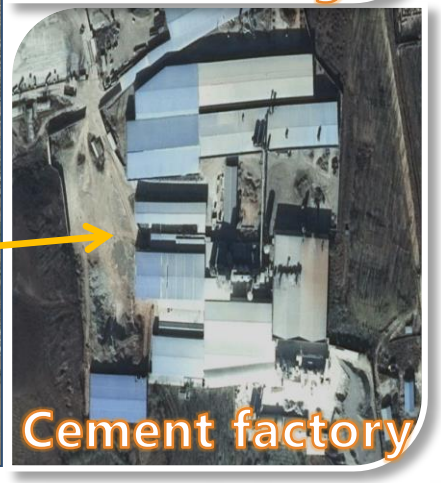
After

Environment Impacts from Surrounding Provinces

- the only way to collect such information

Air pollution sources identified from satellite imagery





Air Pollution Sources Tracking

Factory pollution source demolished but appearing again nearby

2012

2014

Illegal Land Usages

To assist land use and mining law enforcement, frequent monitoring

- **Illegal land occupation**
- **Damage agriculture field and surface mining resources**
- **Illegal sand mining**

Earlier discovery, reporting and law enforcement

Occupying Agriculture land

New Golf Field

Sand Mining

Summary and Benefits

Based on Guaranteed High Resolution Satellite Imagery, 21AT Asia provides

- **Updated, objective and independent land cover survey - cost effective**
  - Planning of further city development and quality of life improvement in the city
  - Evaluation of quality of life in the city
  - The bases for Change Surveillance
- **Change Surveillance of Interested Features and Targeted Areas**
  - Keep city in order – running smooth and efficient
  - For law enforcement
- **City Management Operation and Reporting Software**
  - All geospatial data integration
  - Comprehensive analysis
  - Statics and various government reports
  - Government operation software

Conclusion

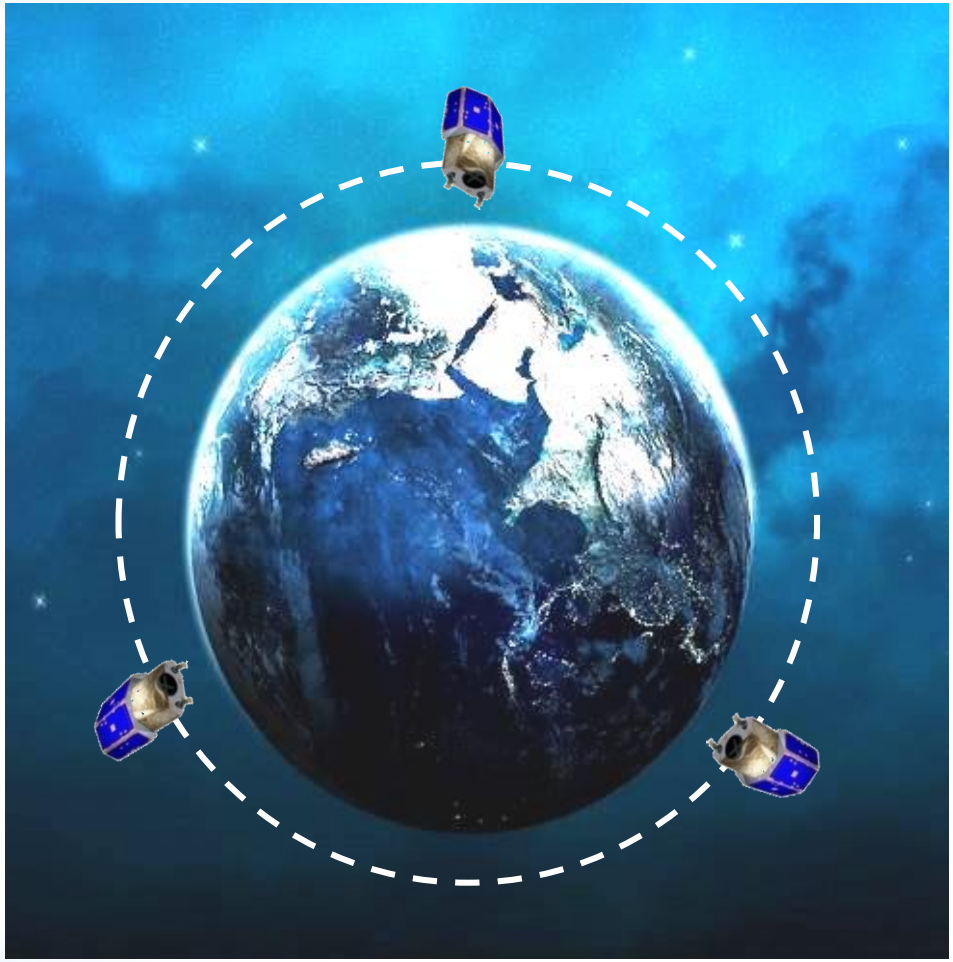
- **The traditional ground survey and monitoring require a lot of manpower and resources, are incomplete and costly process, so that out of date**
- **In contrast, Observing from Sky provides**
  - Complete picture of the city efficiently that makes the regular status update possible
  - Independent and objective data out of influence from human interest
- **In addition, satellite observation provides monitoring of neighboring provinces for environment protection.**

An Innovative approach for land cover survey and monitoring

Enable Intelligent City Management

TripleSat Constellation

Designed to be Compatible with IKONOS Technical Specifications



Sat. Num.	3
Orbit	SSO, 650km LTAN:10:30am
GSD	PAN: <1m, MS: <4m
Swath Width	24km
MS bands	B/G/R/NIR
Off-pointing	±45°
Revisit	1 day
Manufacturer	SSTL in UK

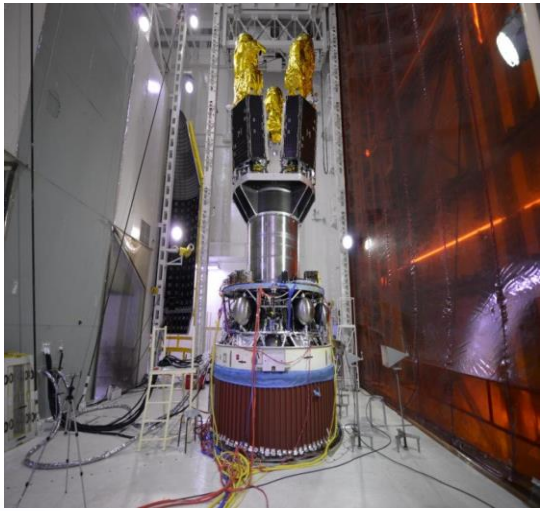
First purposely built <1m 3 identical satellite constellation with daily revisit capability

Integrated Satellites In the Manufacture - SSTL

State-Of-Art Low Cost Small Satellites

TripleSat Constellation is ready for launch and prior shipping to launch side

Integration with PSLV-XL Launcher



Last Glance of TripleSat in Satish Dhawan Space Centre in India

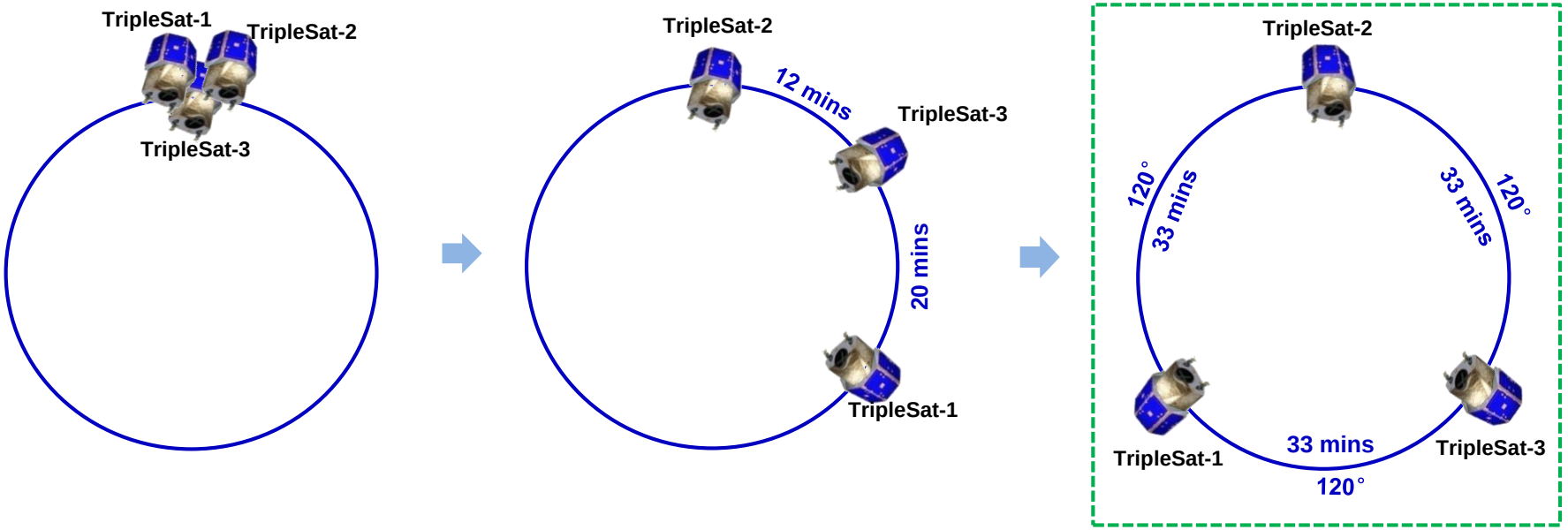
Successful Launch on 10 July

- Three <1m Satellites were launched by PSLV-XL on 10 July
- TripleSat-1, TripleSat-2 & TripleSat-3 are injected to 650km sun synchronized orbit
- Three ground stations from three different locations used for initial commissioning
  - Svalbard of Norway
  - Borden of UK
  - Guildford of UK
- Telemetry from all three satellites were received on their first pass over the dedicated ground station

First <1m Satellite Constellation Put Into Orbit Using Single Launcher

Phasing for the Constellation

- One week after the launch, on board propulsion systems was fired to move the satellites to their designated positions in the constellation
- Now, they are in the designated positions, 33 minutes/120° apart
- The propulsion system will continuously maintain the satellite positions



Launch

18 August

Now and Operation

Unique daily targeting capability made possible by three satellite constellation

Daily Imaging Anywhere on the Earth

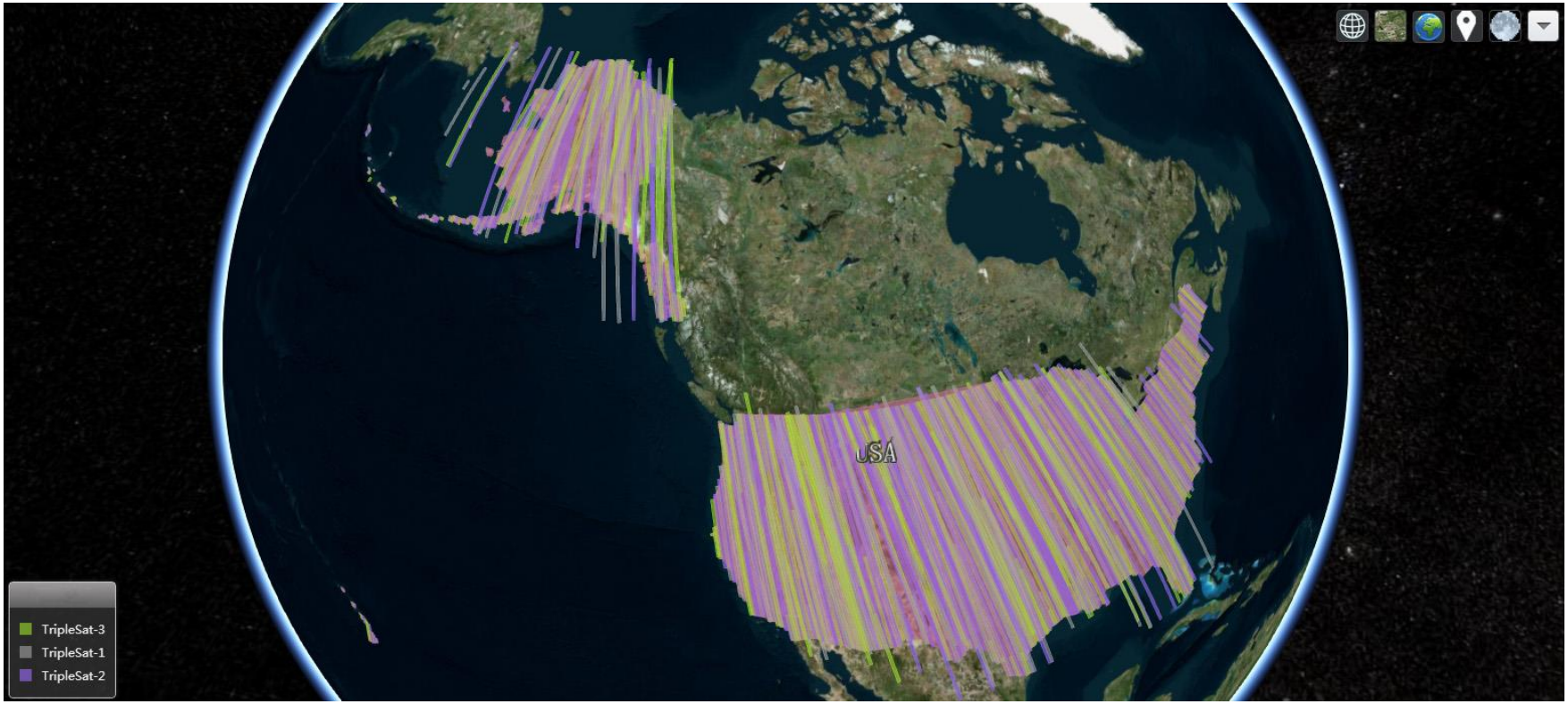
- TripleSat Constellation launched by a single launcher
- Phasing three satellites 33 minutes after each other to form the ideal constellation
- Able to target anywhere on the Earth once per day using off-pointing capability (45° Max.)

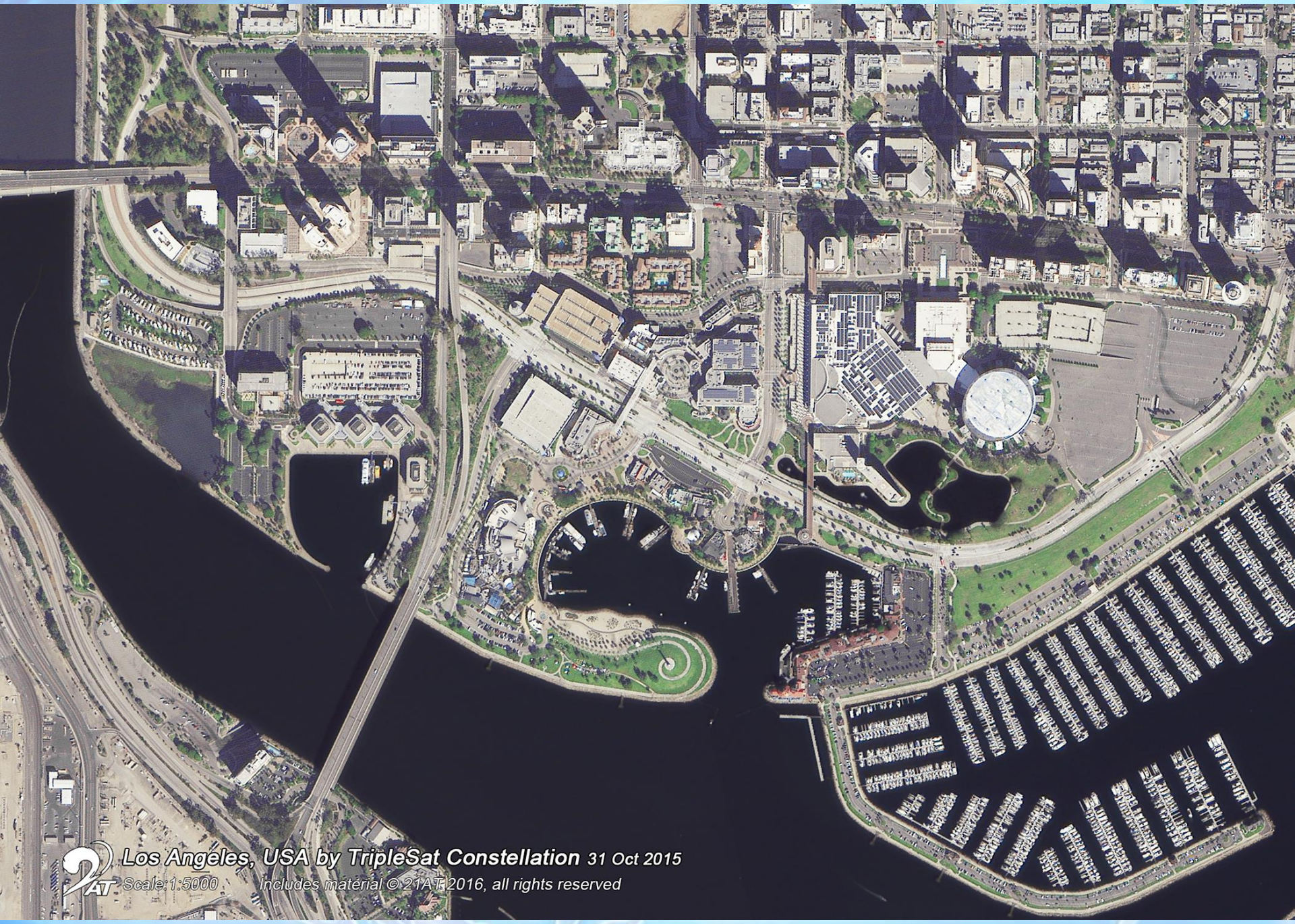
Latitude	Off-pointing / revisit period			
	5°	15°	25°	35°
0°	8 days	3 days	2 days	Daily
±10°	8 days	3 days	2 days	Daily
±20°	8 days	3 days	2 days	Daily
±30°	7 days	3 days	2 days	Daily
±40°	7 days	2 days	2 days	Daily
±50°	6 days	2 days	Daily	Daily
±60°	4 days	2 days	Daily	Daily
±70°	3 days	Daily	Daily	Daily
±80°	2 days	Daily	Daily	Daily

With frequent revisit capability, offering "dependable data" services

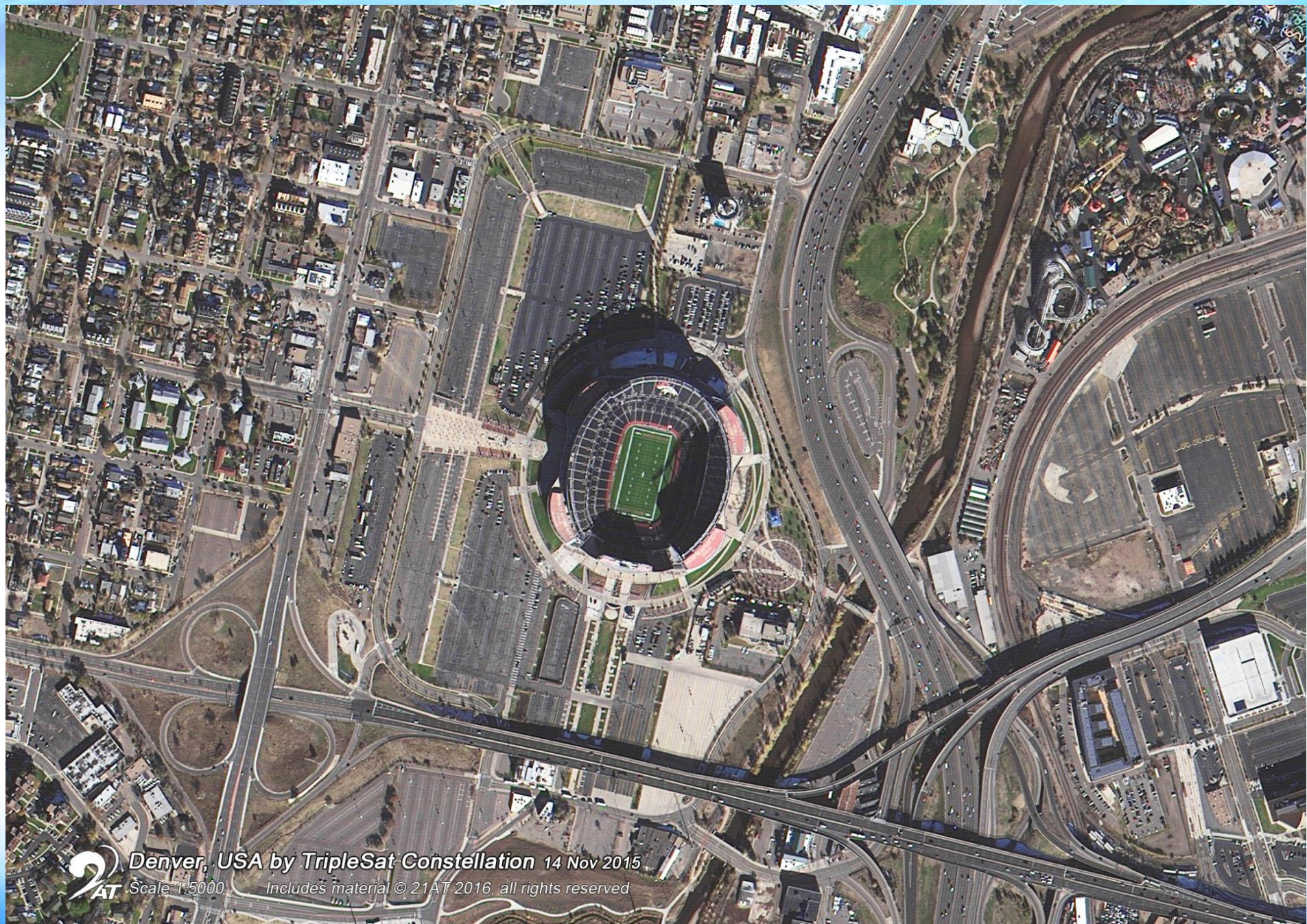
TripleSat Constellation – The United States Coverage

With three satellites in constellation, the whole United States can be covered within 52 days theoretically within off oppoingting < 30˚

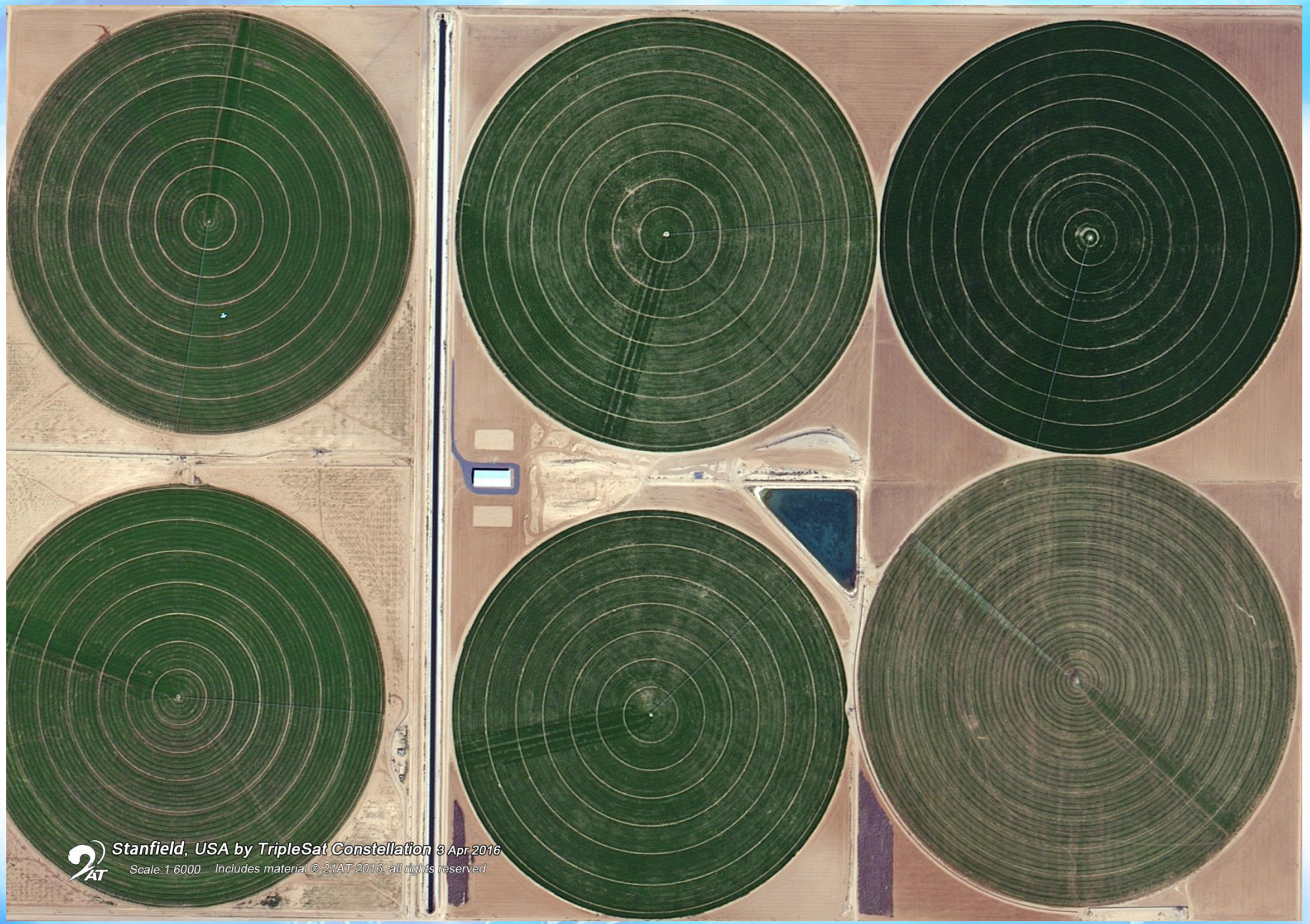



Los Angeles, USA by TripleSat Constellation 31 Oct 2015
Scale:1:5000
Includes material © 21AT 2016, all rights reserved

Denver，Sports Authority Field at Mile High，2015-11-14



Arizona，Stanfield，2016-04-03

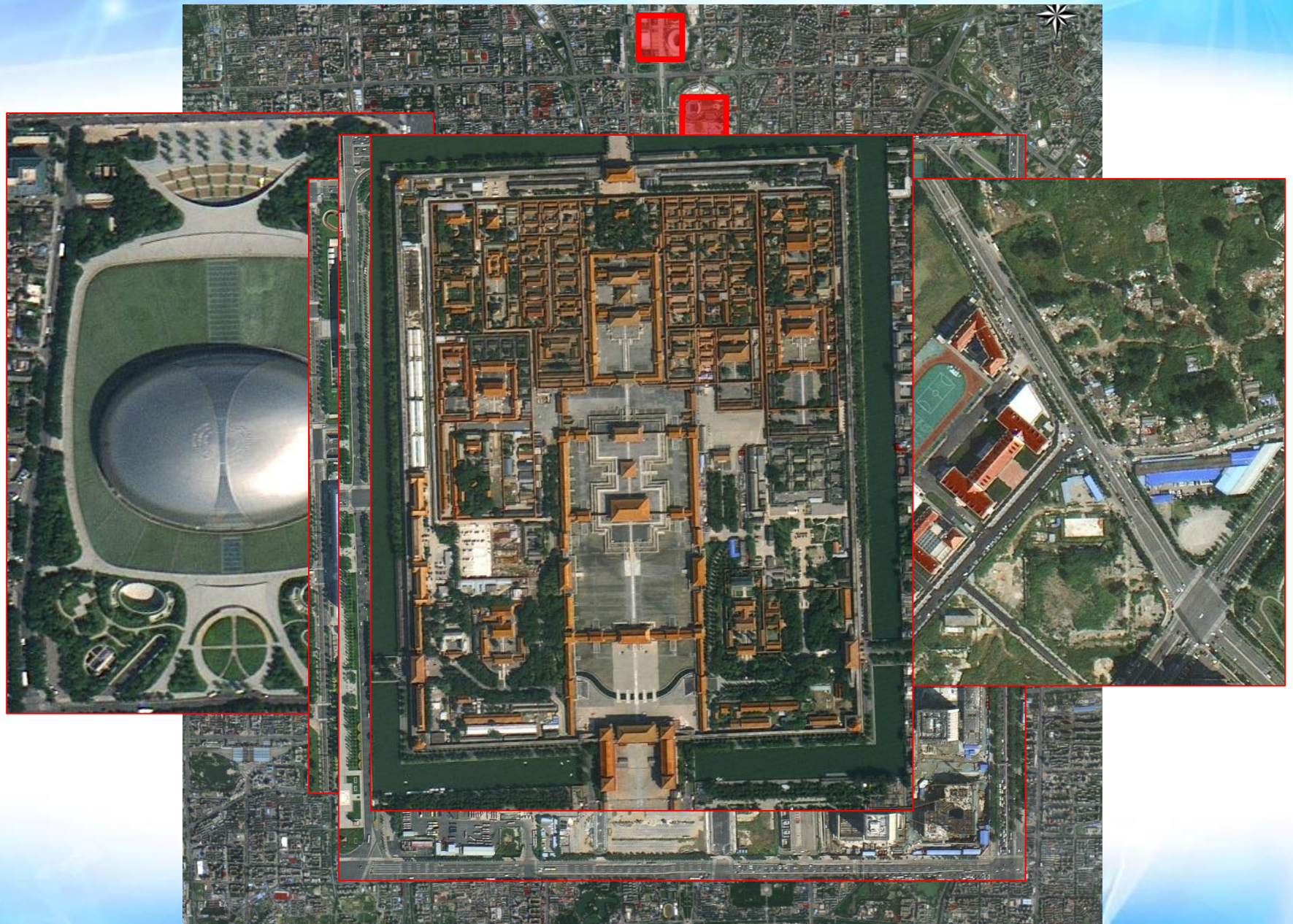


Washington，The White House，2015-10-12

Washington，Washington Monument，2015-10-12，TripleSat

Washington，Memorial Amphitheater，2015-10-12

Beijing, China, 7th of September



C.7.2 Absolute Radiometric Calibration Accuracy

Requirements: The nominal absolute radiometric calibration accuracy for all products, shall be <7% following in-orbit vicarious calibration

	FM1	FM2	FM3
Blue	3.26%	3.27%	3.27%
Green	3.09%	3.10%	3.10%
Red	3.18%	3.14%	3.16%
NIR	3.30%	3.11%	3.25%
PAN	3.44%	3.29%	3.29%

Carried out by Steve Mackin

C.7.3 Relative band-to-band stability

Requirements: The nominal relative band to band stability within any image shall be better than 4%

The red band was used as a reference band as it is least affected by atmospheric influences (0%)

	FM1	FM2	FM3
Blue	3.82%	1.51%	3.1%
Green	1.32%	0.57%	0.95%
Red	0%	0%	0%
NIR	1.67%	1.43%	0.34%
PAN	1.39%	0.62%	1.05%

C.7.4 Signal-to-Noise Ratio (SNR)

Requirements:

The SNR for Very High Resolution Imager (VHRI) products, before ground processing, shall be at least 100:1 (1-sigma) for all channels

The SNR was calculated for 6 CDS using 2 TDI stages on the Multispectral bands and 16 TDI stages on the PAN band.

Band	SNR
Blue	220:1
Green	230:1
Red	200:1
NIR	145:1
PAN	170:1

C.7.5 MTF

Requirements:

For the VHRI the in-orbit MTF on axis, disregarding atmospheric effects, shall be:

VHRI-PAN:	>10% (at PAN Nyquist frequency)
VHRI-MS/Blue:	>20% (at colour Nyquist frequency)
VHRI-MS/Green:	>20% (at colour Nyquist frequency)
VHRI-MS/Red:	>20% (at colour Nyquist frequency)
VHRI-MS/NIR:	>20% (at colour Nyquist frequency)

	Average MTF@Nyquist		
	FM1	**FM2**	**FM3**
Blue	35.0%	37.9%	31.5%
Green	37.5%	38.0%	38.5%
Red	37.5%	39.0%	35.5%
NIR	32.9%	34.5%	24.3%
PAN	20.6%	19.1%	17.3%

C.9.2 Geo-location (2 Star Trackers)

Requirement:

In a condition where the Sun, Earth or Moon are not in the blinding zones of either star tracker, the geo-location accuracy at nadir after ground processing, shall be <50m (1σ) (without GCPs)

During commissioning suitable image data was captured from all three satellites and compared with a reference data set

NAIP dataset, http://viewer.nationalmap.gov/viewer/). For height control a digital elevation model was used (CGIAR SRTM v4, http://srtm.csi.cgiar.org/)

The data captured during this test had AOCS data from two star trackers

	FM1	FM2	FM3
RMS x [m]	7	6	6
RMS y [m]	17	13	16

Started Commercial Operation Services in April 2016

- After the completion of
  - Radiometric and Geometric Calibration
  - Performance verification tests
- The initial service will start in the middle of November 2015

Specifications	Contract Value	In Orbit Result
SNR	>100:1	145 - 230
MTF	Pan >10% MS > 20%	17.3% - 20.6% 24.3% - 39%
Swath width	23.4km	24km
Geo-location	<50m	<20m

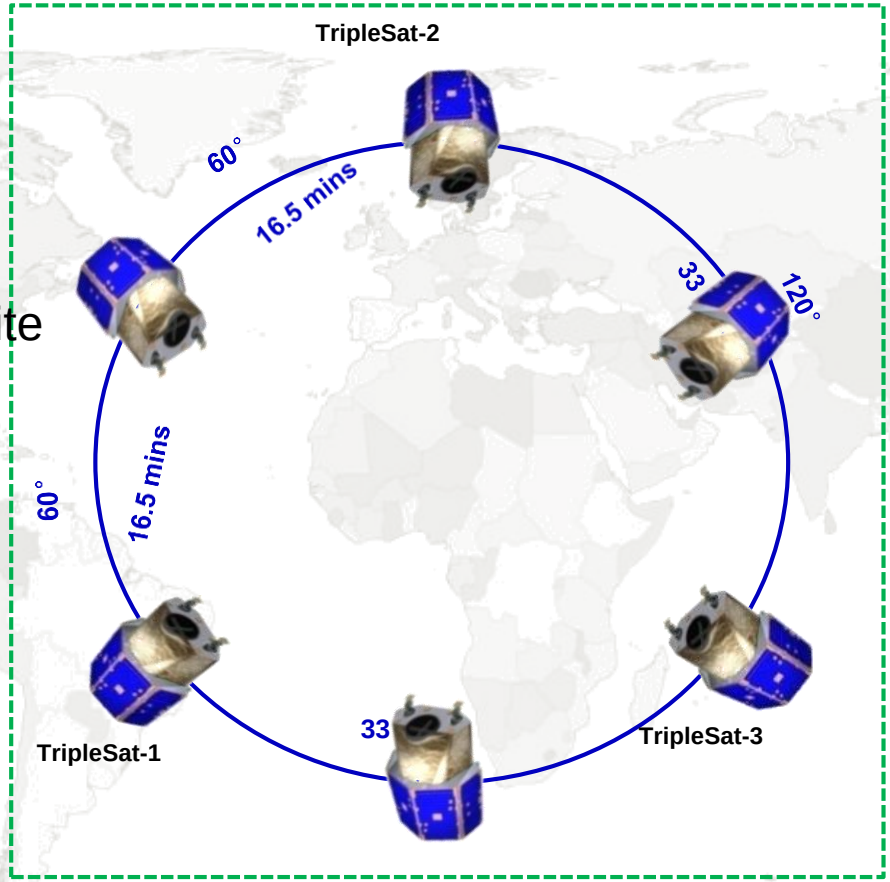
A Significant Milestone for the Industry

Benefits to Worldwide Customers

- **Dependable data source for operational monitoring**
  - Able to target anywhere on the Earth once per day with high resolution image
- **The best combination of spatial resolution and time resolution**
  - <1m GSD with 24km swath
- **Compatible technical specifications with those of IKONOS**
  - Well understood applications
- **Identical payloads plus cross calibration over three satellites**
  - Convenient for quicker applications
- **In addition to along track Stereo imaging by single satellite, cross track Stereo imaging by adjacent satellites**
  - Made possible by three satellites in a constellation
- **Cloud free image selection for efficient download**
  - Enabled by large on-board memory
- **“Operational monitoring of the Changes - intelligent management”**
  - Creating new business opportunity for our customers
- **Comprehensive application expertise**
  - Provide in depth application supports

Future Plan

- **Open for Participation in TripleSat Constellation/Beijing-2**



- **One of my responsibilities is to look at Beijing - 3 mission after the international sales is under way**

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Thank You!

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